AGRICULTURE

Project Fact Sheet

Multi-Plant Component Harvesting Equipment for Inexpensive Sugars from Wheat Residues

Benefits

- Improved economics for use of biomass sugars in industrial applications
- Higher fermentable sugar yield due to lower lignin content
- Improved energy efficiency in preparation of fermentable sugars
- Optimized harvesting and separation of value-added biomass components
- Enhanced components process for degradation of cellulosic material into sugars
- Reduced lignin content co-product/ waste stream
- Potential 2020 target market is 22,500 combines
- Projected 2020 process energy savings are 17.6 trillion Btu per year from improved process and harvesting platform
- Projected 2020 fossil fuel feedstock displacement on a straw-to-ethanol basis is 129 trillion Btu per year

Applications

Biobased industries will directly benefit from the ability to improve the economics of supplying low cost biomass sugars. Optimization of the biomass, harvesting, and initial process should increase the demand for renewable feedstock to be used in a variety of industrial applications. Improved control and sensor systems for agricultural harvesting platforms that allow single-pass, multi-component harvesting will result in a new, more efficient generation of harvesters. Control of lignin synthesis may also find application in the forest products industry.

Selective Harvesting of Wheat Straw for Use in Biobased Products

Research in biobased products has historically focused on the conversion of biomass sugars to products and overlooked the importance of ensuring availability of low-cost biomass feedstock. The production of sugars from wheat straw faces several obstacles including high capital costs and energy consumption, waste streams, and the quality of the biomass feedstock. Together, these obstacles can negatively impact the use of wheat straw as a biomass feedstock. To address these problems, Iowa State University and its partners are joining in a project to bring three separate research areas together. The first two areas, modeling within a virtual environment and system controls, are focused on developing single-pass harvesting equipment that selectively harvests multiple crop components. The third area, genetics, is focused on reducing the lignin content in wheat straw and optimizing the processing of cellulosic plant components to low-cost sugars.

The wheat straw and grain will be more efficiently harvested with a single-pass, multi-component harvester. The combination of an advanced sensor and control system with a modified harvester will enable the in-field separation of desired plant components (e.g., straw, grain) from the less-desirable components (e.g., nodes, chaff). The less-desirable components will be returned to the field as organic matter soil amendments. The wheat straw will be used to evaluate and optimize an existing process to convert the cellulosic biomass into fermentable sugars.

Lignin is an important component in plants because it imparts strength to cell walls. However, it severely limits the use of agricultural residues in biobased products by increasing the cost of processing the biomass into its sugar building blocks and creating a large, lower-value co-product/waste stream in biomass sugar production. Lignin also competes with the production of the desired cellulosic sugars in live plants. Therefore, decreasing the lignin content in wheat straw should result in a higher yield of useful sugars from the straw. As a result of the low lignin content, a process step may be eliminated and the lignin co-product/waste stream will be substantially reduced.

Figure 1. Conceptual Illustration of the Single-Pass Harvester

Project Description

Goal: Increase the economic feasibility of using wheat straw as a feedstock for biobased products by: 1) developing a single-pass harvester to selectively harvest wheat straw and grain; 2) reducing the lignin content in wheat straw; and 3) optimizing an existing technology for wheat straw degradation into fermentable sugars.

The development of virtual reality based modeling and design tools will be important in the design of a single-pass harvester. The virtual engineering design platform will simulate the biomass fractionation flow in the threshing chamber of a working grain combine and serve as a design workbench. This research will be undertaken by Iowa State University (ISU) and will bring together computational modeling, experimental results, and the tools necessary to support the engineering design of a single-pass harvester.

The Idaho National Engineering and Environmental Laboratory (INEEL) will develop a stress/strain mechanical threshing model to quantify how variables such as moisture content and wheat variety affect the anatomical breakup of straw. ISU and INEEL will co-develop a computational fluid dynamics (CFD) model of the experimentally observed biomass separation in INEEL's wind tunnel. CFD modeling results will be used to simulate the fractionation flow in the threshing chamber of a combine harvester. The models, experimental results, and engineering designs will be integrated into the virtual engineering workbench developed by ISU to create a virtual test bed for new harvester designs.

To exploit lignin gene regulation, the University of Idaho and INEEL will identify, clone, and characterize the gene(s) responsible for lignin synthesis. Once the gene(s) has been identified, the standard antisense method will be used to reduce the activity of the lignin gene. Transformed wheat cultures will be regenerated into plants and INEEL will test plant selections for reduced lignin content using the acid hydrolysis method. Promising plant selections will be evaluated by Arkenol to determine lignocellulose extractability and to assess their correlation with process improvements that correlate with less lignin. Arkenol will also determine feedstock characteristics (e.g., initial and final compositions, ash content, particle size distribution) through each step of Arkenol's Concentrated Acid Hydrolysis Process.

INEEL will develop an advanced control and sensor system for use in a new generation of agricultural harvesting platforms. The control/sensor system will be utilized to optimize the harvesting and separation of value-added biomass components during harvest, while minimizing total grain loss.

Progress and Milestones

- Intelligent software
- Intelligent sensors
- Physical model
- Computation model
- Tissue specific lignin genes

Project Partners

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